



**EDGEWOOD**  
CHEMICAL BIOLOGICAL CENTER  
U.S. ARMY SOLDIER AND BIOLOGICAL CHEMICAL COMMAND

ECBC-TR-026

DOMESTIC PREPAREDNESS PROGRAM: LIQUID SULFUR MUSTARD AND  
SARIN CHALLENGE/VAPOR PENETRATION SWATCH TESTING  
OF BLUE MAX HAZMAT SPLASH CLOTHING  
MODEL B

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April 1999

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## Preface

The work described in this report was authorized under the Expert Assistance (Personal Protective Equipment Evaluation) Program for the U. S. Army Edgewood Research, Development and Engineering Center (ERDEC)\* Program Director for Domestic Preparedness. The work was started in May 1998 and completed in July 1998.

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\* Now known as the U.S. Army Edgewood Chemical Biological Center.

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DOMESTIC PREPAREDNESS PROGRAM: LIQUID SULFUR MUSTARD AND  
SARIN CHALLENGE/VAPOR PENETRATION SWATCH TESTING OF  
BLUE MAX HAZMAT SPLASH CLOTHING, MODEL B

1. INTRODUCTION

Under the Domestic Preparedness (DP) Expert Assistance (Personal Protective Equipment (PPE) Evaluation) Program, the U. S. Army Edgewood Research, Development and Engineering Center (ERDEC)\* was tasked to perform testing of swatches taken from commercially-available Level B suits currently being used by emergency responders from cities involved in this program. The testing was performed by the Design Evaluation Group, Surety Team, Methodology, Instrumentation and Test Office, Engineering Directorate. The test procedure was jointly developed and agreed upon by ERDEC and the U. S. Army Natick, Research, Development and Engineering Center (NRDEC) (written communication, M. Chin, NRDEC, 1 May 97).

2. MATERIALS AND METHODS

2.1 Suit Description.

The Blue Max Hazmat suit was manufactured by Mine Safety Appliances Co., (Pittsburgh, PA) and was blue in color. The model number was B. Figure 1 is a digital photograph of the label found inside the suit.

2.2 Swatch Preparation.

The day before testing was scheduled to begin, the suit was picked up from Mask Issue and transported to the laboratory. The suit was folded up for transport and was hung on a hanger once in the laboratory. The suit was stored this way during and after testing.

The swatch locations to be sampled were given in the PPE Test Team Work Contract for Level A Ensembles (written communication, R. Belmonte, Engineering Directorate, ERDEC, 25 June 1997). These swatch sampling locations were listed as suit material (SM), suit seam (SS), visor material (VM), zipper/suit material seam (ZP), glove (GL), and visor material/suit material seam (SV). The suit did not come with gloves and did not have a visor. The zipper/material suit material seam was identical to the suit seam so it was not separately tested. The suit did come with booties. The decision was made to take swatches from five locations; the crotch seam (CS), boot material (BM), boot seam (BS), SM, and SS. The swatches were normally cut the day before testing and conditioned overnight at the test conditions. For a Monday test, swatches were cut Friday and conditioned over the weekend. Normally, the swatches would be laid in the environmental cabinet for conditioning.

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\* Now known as the U.S. Army Edgewood Chemical Biological Center.

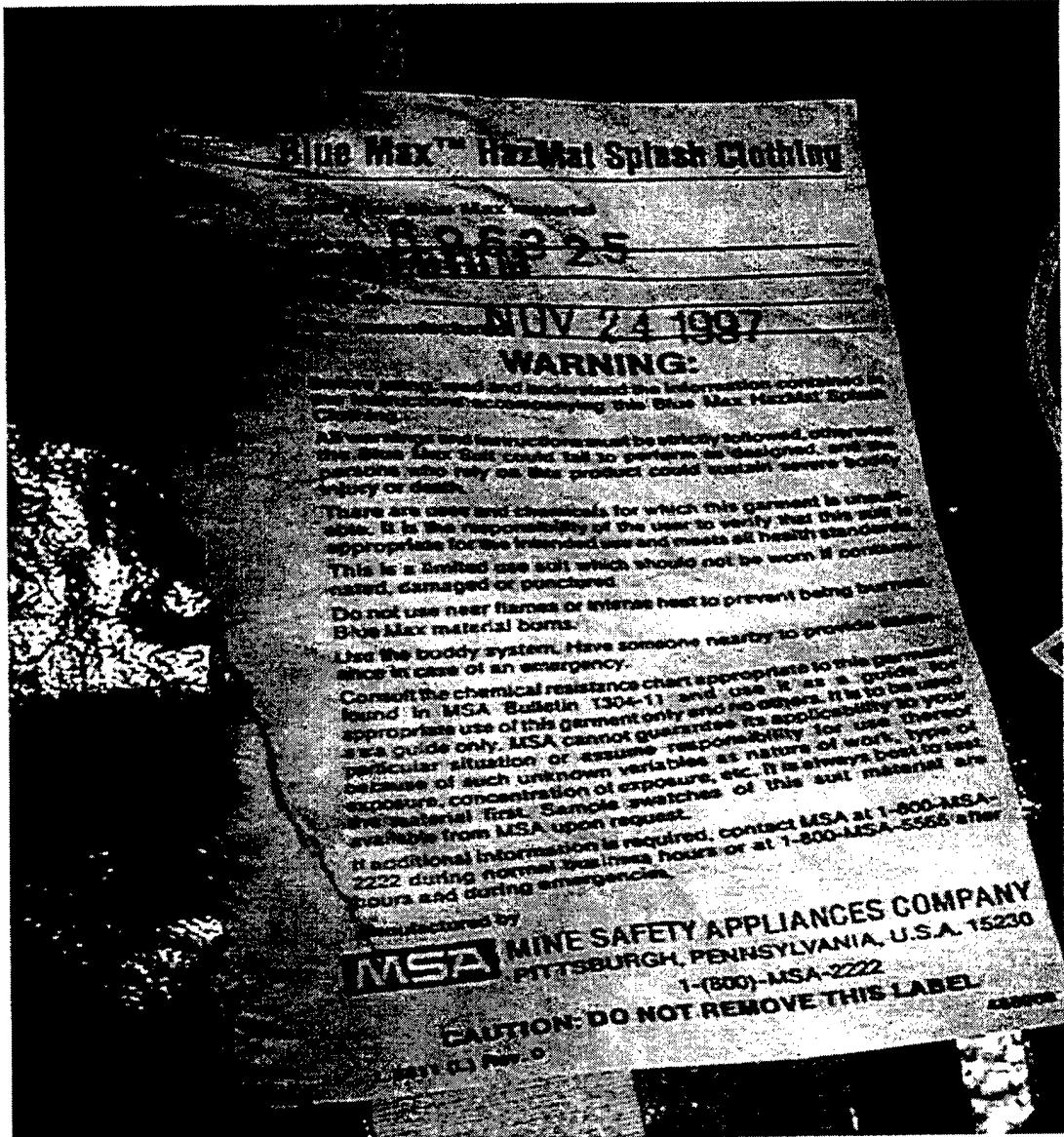


Figure 1. Blue Max Label

The swatches were numbered in accordance with the PPE Test Team Work Instructions (written communication, R. Belmonte, Engineering Directorate, ERDEC, 11 June 1997); for example LC-MSA-SM-01, etc. All swatches were cut in triplicate, one at a time on a sample press. The swatch diameter was 2 in.

The reference material was 80-mil silicone, using the M45 mask formulation, prepared by Malcolm Little of the M45 mask team. Preparation and conditioning were the same as for the suit swatches.

## 2.3 Test Procedure.

The procedure agreed upon by ERDEC and NRDEC was derived from the report entitled, "Permeation and Penetration Testing of Air Permeable, Semi-permeable and Impermeable Materials with Chemical Agents or Simulants (Swatch Testing)" dated 3 March 1997. The Modified Static Diffusion Procedure is found in Appendix A of this report. Subsequent to the agreement, ERDEC personnel determined that the usage of the 80-mil silicone did not meet the definition of a positive control. The silicone swatches were used as an indication of agent vapor permeation. Equipment and schedule limitations prevented the use of negative controls. The terminology of the test procedure was not modified to reflect these changes.

The TOP permeation cell was used and a digital photograph of one is given as Figure 2.

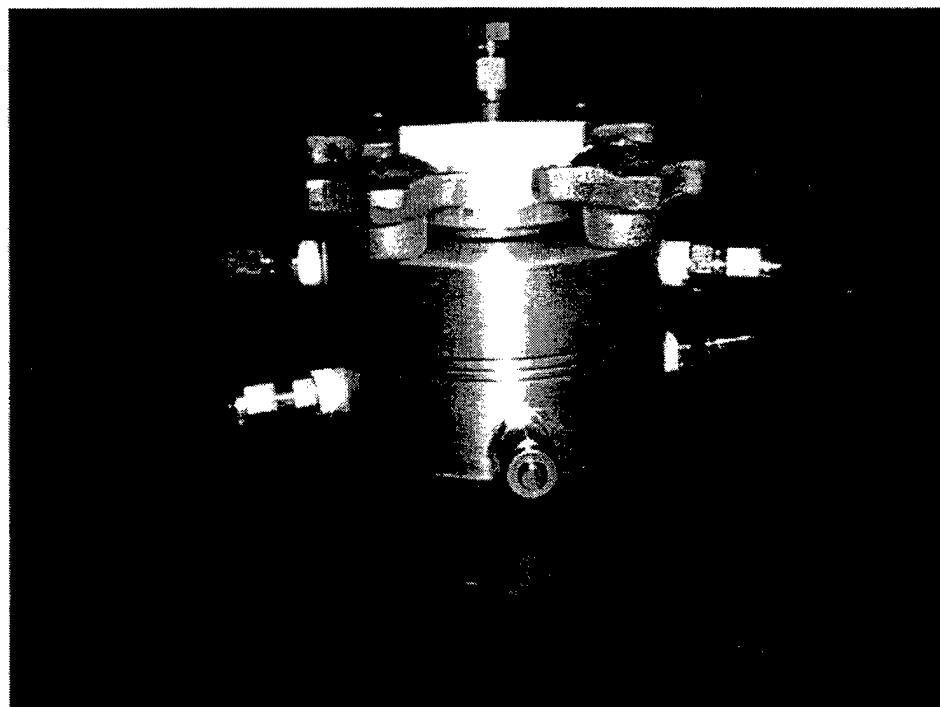


Figure 2. TOP Permeation Cell

The remainder of the test apparatus consisted of the following.

- Plastic environmental cabinet with sliding doors containing a permeation cell rack, circulating blower, and heat source (Figure 3).
- Flow/temperature/relative humidity control system; (Miller-Nelson Research Corporation, Monterey, CA) model HCS-410.
- Flow control system; (Tylan General Incorporated, Torrance, CA) Dynamass model FM-8.

- Mass flow controllers; (Tylan General Incorporated, Torrance, CA) model FC-260.
- Calibrated Vaisala humidity and temperature indicator.
- MINICAMS, serial number 2362, and Stream Selection System (CMS Research Corporation, Birmingham, AL). Illustrated in Figure 4.

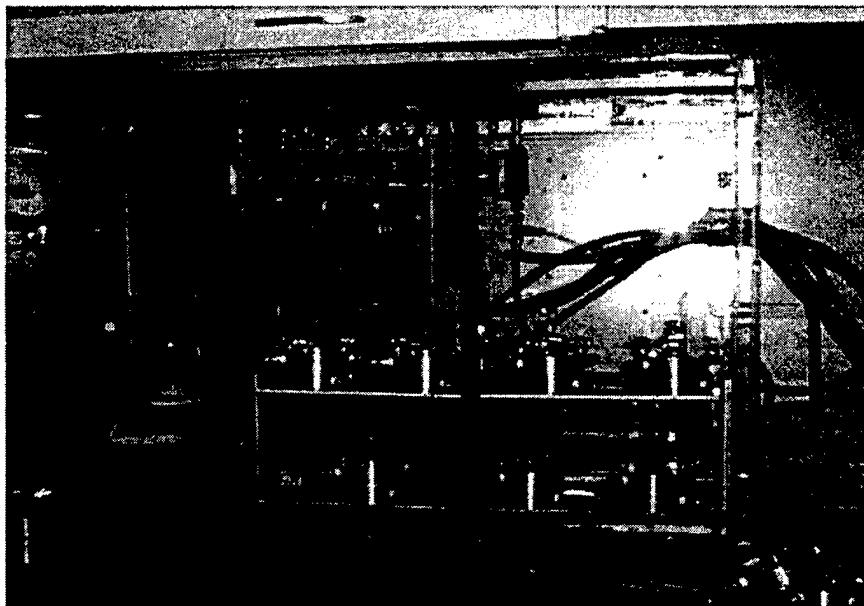


Figure 3. Environmental Cabinet

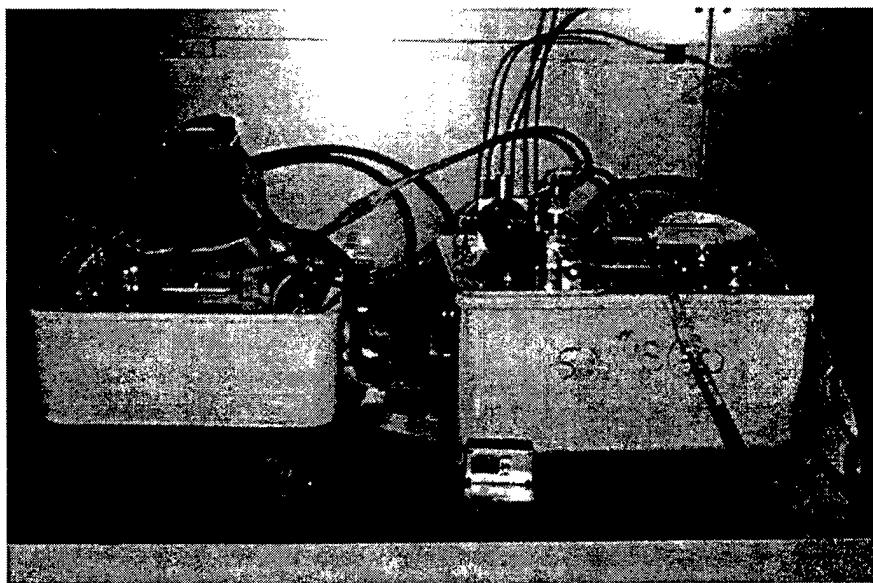


Figure 4. MINICAMS and Stream Selection System

### 3. RESULTS AND DISCUSSION

#### 3.1 HD Results.

The HD permeation results are given in Appendix B as Tables B-1 through B-5. Average elapsed time was not used. The actual time that each swatch was sampled by the MINICAMS is shown.

The MINICAMS minimum detection limit was 1.0 ng for all test days. There were no visible effects on any of the materials from HD exposure. Cumulative permeation was lowest for the crotch seam swatches. Cumulative permeation was similar for all other swatches including the suit material.

The average temperature was controlled at 90 +/- 2 °F, and 50 +/- 10% RH was the average for all tests. The temperature and RH data collected during the tests were lost due to a malfunction in the data-collection computer. The first MINICAMS cycle for each swatch was taken before agent was applied. This cycle served as an indication that no agent vapor was present prior to the start of the test. Negative control and positive control swatches were not used.

#### 3.2 GB Results.

The GB permeation results are given in Appendix C as Tables C-1 through C-5.

The MINICAMS minimum detection limit was 0.4 ng for all test days. There were no visible effects on any of the materials from GB exposure. Cumulative permeation was highest for one suit seam swatch and two boot seam swatches (several times higher than for the suit material). Most other swatches had cumulative permeation that was similar to or lower than the suit material.

The average temperature was controlled at 90 +/- 2 °F, and 50 +/- 10% RH was the average for all tests. The temperature and RH data collected during the tests were lost due to a malfunction in the data-collection computer. The first MINICAMS cycle for each swatch was taken before agent was applied. This cycle served as an indication that no agent vapor was present prior to the start of the test. Negative control and positive control swatches were not used.

3.3        Material Thickness.

Prior to conducting the HD and GB testing, thickness measurements of the suit material and the boot material were made. A swatch of material was cut from the suit immediately adjacent to the area from which the agent swatches were taken. Twenty-four thickness measurements were taken on each swatch using an Ames dial comparator (B. C. Ames Company, Waltham, MA). The average thickness of the suit material swatch was 0.023 in. The average thickness of the boot material swatch was 0.025 in.

**APPENDIX A**  
**MODIFIED STATIC DIFFUSION PROCEDURE**

## **MODIFIED STATIC DIFFUSION TEST**

This test procedure was adapted from the "Semipermeable and Impermeable Materials Static Diffusion Penetration Testing (Liquid Agent Challenge/Vapor Penetration; delta p = 0, Single Flow Test) given in Test Operations Procedure (TOP) 8-2-501 dated 3 Mar 97.

The following procedure will be used:

Upon receipt of a suit, all available information concerning the suit will be recorded; date of manufacture, lot number, serial number, materials of construction, etc.

From each suit, 3 each 1 and 15/16 in. diameter material swatches will be taken for HD and a like number taken for GB. Depending upon the suit configuration, three seam swatches (same diameter) will be taken plus triplicate swatches of other flat components such as other seams, visor, gloves, booties, etc. for HD and an equal number for GB. Each swatch will be placed in an airtight bag and given a unique serial number which will be placed on the bag. A list of serial numbers will be kept with the swatches.

The environmental chamber will be controlled at a temperature of 90 +/- 2 °F , and the maximum achievable RH without occurrence of condensation (70% +/- 10% RH). The temperature and RH readings will be checked weekly with a calibrated meter. The test cell air will be drawn from the chamber air. There will be no system control and data acquisition system. The temperature and RH will be recorded in a computer file. Flow rates will be manually recorded. There will be no differential pressure monitoring since differential pressure gages of sufficient sensitivity are not available.

The TOP test cell will be used. When assembling, the cell lugs will be tightened by hand to finger tight. The flow rate beneath each swatch will be 1 L/min which will be controlled by a linear mass flow controller. The flows will be checked with a calibrated test meter weekly. Each test cell will be checked for leaks after assembly by connecting it to the vacuum source and checking that the inlet flow is the same as the outlet flow on the mass flow controller (cell lugs will be retightened if flows don't match).

The samples will serve as their own negative controls while being preconditioned overnight by being MINICAMS monitored. Eighty mil silicone will be used as a positive control for each test (six suit swatches and one silicone swatch).

Agents GB and HD will be used. The contamination density will be 10 g/m<sup>2</sup> (eight each 1 µl HD droplets or ten each 1 µl GB droplets). A robotic agent application system is not available. The agent will be applied using the click/touch method with a Hamilton repeating dispenser.

Seven swatches will be tested at once. MINICAMS with stream selection system will monitor vapor penetration with a 3-min cycle. There will be three blank sampling intervals following the control. Each swatch will be sampled once every 30 min. The MINICAMS will be standardized weekly.

The test length will be 24 hr.

The test cells and o-rings will be aerated between uses. No other cleaning method will be used.

The data to be reported are cumulative penetration (ng/cm<sup>2</sup>) versus average elapsed time (minutes) for each swatch. The average elapsed time is the sum of the elapsed time for swatch 1 and the elapsed time for swatch 6 divided by 2. All recorded data will be placed in laboratory notebooks and a technical report will be drafted at the conclusion of this effort.

## **Appendix A**

**APPENDIX B**  
**HD TABLES**

Table B-1. MSA BLUE MAX HazMat Model B Suit Material vs. HD Liquid, 10 g/m<sup>2</sup>

Modified Static Diffusion Test, 4 June 1998

Cumulative Penetration (ng/cm<sup>2</sup>)

Minutes	Swatch 1	Minutes	Swatch 2	Minutes	Swatch 3
2	2	5	3	8	1
32	55	35	36	38	13
62	109	65	71	68	25
92	165	95	107	98	38
122	222	125	146	128	52
152	281	155	187	158	67
182	343	185	230	188	83
212	406	215	274	218	100
242	469	245	319	248	117
272	534	275	364	278	135
302	600	305	412	308	155
332	670	335	459	338	171
362	742	365	507	368	187
392	816	395	558	398	207
422	891	425	611	428	229
452	965	455	664	458	253
482	1039	485	716	488	275
512	1113	515	767	518	298
542	1186	545	818	548	319
572	1257	575	868	578	340
602	1327	605	918	608	360
632	1395	635	966	638	380
662	1460	665	1012	668	399
692	1525	695	1056	698	417
722	1590	725	1099	728	434
752	1653	755	1142	758	452
782	1715	785	1184	788	470
812	1776	815	1226	818	489
842	1837	845	1267	848	507
872	1897	875	1309	878	525
902	1956	905	1349	908	542
932	2014	935	1388	938	560
962	2072	965	1427	968	577
992	2129	995	1466	998	594
1022	2185	1025	1503	1028	610
1052	2240	1055	1540	1058	626
1082	2293	1085	1575	1088	641
1112	2341	1115	1606	1118	655
1142	2386	1145	1636	1148	669
1172	2430	1175	1664	1178	682
1202	2471	1205	1686	1208	689
1232	2509	1235	1704	1238	692
1262	2544	1265	1721	1268	695
1292	2580	1295	1738	1298	698
1322	2618	1325	1760	1328	706
1352	2656	1355	1784	1358	717
1382	2694	1385	1807	1388	728
1412	2732	1415	1830	1418	740

## Appendix B

**Table B-2. MSA BLUE MAX HazMat Model B Suit Seam vs. HD Liquid, 10 g/m<sup>2</sup>**  
**Modified Static Diffusion Test, 4 June 1998**  
**Cumulative Penetration (ng/cm<sup>2</sup>)**

Minutes	Swatch 1	Minutes	Swatch 2	Minutes	Swatch 3
11	0	14	0	17	3
41	0	44	0	47	12
71	0	74	0	77	21
101	3	104	3	107	31
131	9	134	10	137	40
161	16	164	17	167	51
191	24	194	24	197	61
221	32	224	32	227	73
251	41	254	40	257	84
281	50	284	49	287	97
311	60	314	59	317	110
341	66	344	65	347	121
371	66	374	65	377	130
401	70	404	69	407	141
431	79	434	78	437	155
461	90	464	88	467	169
491	101	494	99	497	184
521	112	524	110	527	199
551	123	554	121	557	213
581	133	584	131	587	227
611	143	614	141	617	241
641	153	644	151	647	254
671	161	674	159	677	267
701	168	704	163	707	278
731	176	734	168	737	290
761	184	764	177	767	302
791	194	794	186	797	315
821	203	824	195	827	327
851	213	854	205	857	341
881	223	884	215	887	354
911	233	914	224	917	366
941	242	944	233	947	379
971	250	974	242	977	391
1001	259	1004	251	1007	403
1031	266	1034	255	1037	413
1061	272	1064	259	1067	422
1091	279	1094	267	1097	433
1121	286	1124	274	1127	443
1151	293	1154	281	1157	453
1181	300	1184	288	1187	462
1211	304	1214	292	1217	466
1241	304	1244	292	1247	466
1271	304	1274	292	1277	466
1301	304	1304	292	1307	469
1331	304	1334	292	1337	476
1361	304	1364	292	1367	484
1391	304	1394	295	1397	493
1421	304	1424	298	1427	500

## Appendix B

**Table B-3. MSA BLUE MAX HazMat Model B Boot Material vs. HD Liquid, 10 g/m<sup>2</sup>**  
**Modified Static Diffusion Test, 10 June 1998**  
**Cumulative Penetration (ng/cm<sup>2</sup>)**

Minutes	Swatch 1	Minutes	Swatch 2	Minutes	Swatch 3
2	0	5	0	8	2
32	7	35	8	38	16
62	18	65	22	68	28
92	23	95	32	98	38
122	28	125	42	128	48
152	39	155	54	158	58
182	52	185	67	188	70
212	68	215	82	218	82
242	85	245	98	248	95
272	105	275	114	278	109
302	125	305	132	308	124
332	147	335	151	338	139
362	170	365	171	368	156
392	195	395	192	398	174
422	220	425	214	428	193
452	246	455	237	458	212
482	272	485	259	488	231
512	299	515	282	518	250
542	326	545	305	548	270
572	352	575	328	578	289
602	378	605	351	608	308
632	404	635	373	638	327
662	429	665	395	668	345
692	454	695	417	698	363
722	478	725	438	728	381
752	502	755	458	758	398
782	525	785	478	788	415
812	547	815	499	818	432
842	570	845	519	848	449
872	592	875	539	878	465
902	613	905	557	908	481
932	632	935	574	938	495
962	651	965	591	968	510
992	670	995	608	998	525
1022	688	1025	624	1028	539
1052	706	1055	641	1058	553
1082	724	1085	657	1088	567
1112	741	1115	673	1118	580
1142	758	1145	688	1148	594
1172	774	1175	703	1178	607
1202	790	1205	718	1208	620
1232	806	1235	732	1238	633
1262	822	1265	746	1268	645
1292	837	1295	760	1298	658
1322	852	1325	774	1328	670
1352	866	1355	787	1358	682
1382	878	1385	798	1388	691
1412	887	1415	806	1418	699

## Appendix B

**Table B-4. MSA BLUE MAX HazMat Model B Boot Seam vs. HD Liquid, 10 g/m<sup>2</sup>**  
**Modified Static Diffusion Test, 10 June 1998**  
**Cumulative Penetration (ng/cm<sup>2</sup>)**

Minutes	Swatch 1	Minutes	Swatch 2	Minutes	Swatch 3
11	0	14	0	17	3
41	4	44	4	47	14
71	9	74	8	77	23
101	9	104	8	107	27
131	9	134	8	137	27
161	9	164	12	167	27
191	13	194	20	197	31
221	21	224	29	227	39
251	31	254	38	257	48
281	41	284	47	287	57
311	52	314	57	317	66
341	63	344	67	347	76
371	75	374	79	377	87
401	88	404	91	407	99
431	102	434	104	437	111
461	115	464	117	467	123
491	129	494	130	497	135
521	144	524	143	527	148
551	158	554	157	557	160
581	172	584	170	587	173
611	185	614	183	617	185
641	199	644	195	647	197
671	212	674	208	677	209
701	225	704	220	707	220
731	238	734	232	737	232
761	251	764	244	767	243
791	263	794	256	797	254
821	275	824	267	827	265
851	287	854	279	857	276
881	299	884	290	887	287
911	310	914	300	917	297
941	321	944	310	947	307
971	331	974	320	977	317
1001	341	1004	330	1007	326
1031	351	1034	340	1037	336
1061	361	1064	349	1067	345
1091	371	1094	359	1097	354
1121	381	1124	368	1127	363
1151	390	1154	377	1157	372
1181	400	1184	386	1187	381
1211	409	1214	396	1217	390
1241	418	1244	404	1247	395
1271	427	1274	413	1277	399
1301	435	1304	417	1307	403
1331	440	1334	417	1337	403
1361	440	1364	417	1367	403
1391	440	1394	420	1397	406
1421	440	1424	422	1427	411

## Appendix B

**Table B-5. MSA BLUE MAX HazMat Model B Crotch Seam vs. HD Liquid, 10 g/m<sup>2</sup>**  
**Modified Static Diffusion Test, 1 July 1998**  
**Cumulative Penetration (ng/cm<sup>2</sup>)**

Minutes	Swatch 1	Minutes	Swatch 2	Minutes	Swatch 3
1	0	7	0	13	0
31	0	37	0	43	0
61	0	67	0	73	0
91	0	97	0	103	0
121	0	127	0	133	0
151	0	157	0	163	0
181	0	187	0	193	0
211	0	217	0	223	0
241	3	247	0	253	0
271	8	277	0	283	0
301	15	307	0	313	0
331	21	337	2	343	0
361	29	367	7	373	0
391	36	397	12	403	0
421	43	427	17	433	0
451	50	457	23	463	0
481	57	487	28	493	0
511	64	517	33	523	0
541	71	547	38	553	0
571	78	577	40	583	0
601	84	607	43	613	0
631	91	637	47	643	0
661	97	667	50	673	0
691	104	697	50	703	0
721	110	727	50	733	0
751	116	757	50	763	0
781	122	787	50	793	0
811	128	817	50	823	0
841	134	847	50	853	0
871	139	877	50	883	0
901	145	907	50	913	0
931	150	937	50	943	0
961	155	967	50	973	0
991	161	997	50	1003	0
1021	166	1027	50	1033	0
1051	170	1057	50	1063	0
1081	173	1087	50	1093	0
1111	173	1117	50	1123	0
1141	173	1147	50	1153	0
1171	173	1177	50	1183	0
1201	173	1207	50	1213	0
1231	173	1237	50	1243	0
1261	173	1267	50	1273	0
1291	173	1297	50	1303	0
1321	173	1327	50	1333	0
1351	173	1357	50	1363	0
1381	173	1387	50	1393	0
1411	173	1417	50	1423	0

## Appendix B

**APPENDIX C**  
**GB TABLES**

**Table C-1. MSA BLUE MAX HazMat Model B Suit Material vs. GB Liquid, 10 g/m<sup>2</sup>**  
**Modified Static Diffusion Test, 15 June 1998**  
**Cumulative Penetration (ng/cm<sup>2</sup>)**

Minutes	Swatch 1	Minutes	Swatch 2	Minutes	Swatch 3
2	0	5	0	8	0
32	0	35	5	38	9
62	25	65	40	68	43
92	77	95	102	98	95
122	129	125	161	128	144
152	174	155	212	158	186
182	214	185	256	188	223
212	247	215	293	218	254
242	276	245	325	248	281
272	302	275	355	278	306
302	326	305	382	308	329
332	349	335	407	338	350
362	370	365	431	368	370
392	389	395	452	398	388
422	406	425	472	428	404
452	422	455	489	458	420
482	437	485	506	488	434
512	451	515	521	518	447
542	464	545	536	548	459
572	475	575	549	578	470
602	486	605	561	608	480
632	497	635	572	638	489
662	507	665	583	668	498
692	516	695	592	698	507
722	524	725	602	728	515
752	532	755	610	758	522
782	539	785	618	788	529
812	547	815	626	818	535
842	553	845	633	848	542
872	559	875	640	878	547
902	565	905	647	908	553
932	571	935	653	938	558
962	577	965	659	968	563
992	582	995	664	998	568
1022	587	1025	670	1028	571
1052	589	1055	675	1058	571
1082	589	1085	680	1088	571
1112	589	1115	682	1118	571
1142	589	1145	682	1148	571
1172	589	1175	682	1178	571
1202	589	1205	682	1208	571
1232	589	1235	682	1238	571
1262	589	1265	682	1268	571
1292	589	1295	682	1298	571
1322	589	1325	682	1328	571
1352	589	1355	682	1358	571
1382	589	1385	682	1388	571
1412	589	1415	682	1418	571

## Appendix C

**Table C-2. MSA BLUE MAX HazMat Model B Suit Seam vs. GB Liquid, 10 g/m<sup>2</sup>**  
**Modified Static Diffusion Test, 15 June 1998**  
**Cumulative Penetration (ng/cm<sup>2</sup>)**

Minutes	Swatch 1	Minutes	Swatch 2	Minutes	Swatch 3
11	0	14	0	17	0
41	16	44	32	47	327
71	60	74	122	77	1062
101	116	104	247	107	1882
131	169	134	379	137	2703
161	215	164	509	167	3515
191	254	194	634	197	4316
221	288	224	752	227	5101
251	318	254	863	257	5874
281	346	284	972	287	6652
311	371	314	1080	317	7435
341	395	344	1183	347	8210
371	417	374	1285	377	8969
401	437	404	1382	407	9711
431	456	434	1474	437	10431
461	473	464	1560	467	11129
491	489	494	1639	497	11807
521	503	524	1714	527	12463
551	516	554	1784	557	13098
581	528	584	1850	587	13708
611	540	614	1912	617	14296
641	550	644	1969	647	14863
671	560	674	2024	677	15405
701	569	704	2075	707	15926
731	577	734	2122	737	16425
761	585	764	2168	767	16902
791	592	794	2210	797	17360
821	599	824	2250	827	17801
851	606	854	2289	857	18227
881	612	884	2325	887	18634
911	618	914	2360	917	19025
941	624	944	2392	947	19404
971	629	974	2424	977	19767
1001	634	1004	2454	1007	20115
1031	639	1034	2481	1037	20451
1061	642	1064	2508	1067	20774
1091	642	1094	2533	1097	21085
1121	642	1124	2557	1127	21376
1151	642	1154	2578	1157	21638
1181	642	1184	2597	1187	21879
1211	642	1214	2616	1217	22111
1241	642	1244	2634	1247	22334
1271	642	1274	2651	1277	22549
1301	642	1304	2667	1307	22754
1331	642	1334	2682	1337	22949
1361	642	1364	2697	1367	23141
1391	642	1394	2711	1397	23329
1421	642	1424	2725	1427	23504

## Appendix C

**Table C-3. MSA BLUE MAX HazMat Model B Boot Material vs. GB Liquid, 10 g/m<sup>2</sup>**  
**Modified Static Diffusion Test, 17 June 1998**  
**Cumulative Penetration (ng/cm<sup>2</sup>)**

Minutes	Swatch 1	Minutes	Swatch 2	Minutes	Swatch 3
1	0	4	0	7	0
31	9	34	4	37	3
61	23	64	12	67	10
91	38	94	25	97	20
121	60	124	43	127	34
151	84	154	63	157	50
181	107	184	82	187	66
211	128	214	101	217	81
241	148	244	117	247	96
271	167	274	133	277	109
301	183	304	147	307	121
331	199	334	161	337	132
361	212	364	173	367	143
391	225	394	184	397	152
421	237	424	195	427	161
451	248	454	204	457	169
481	258	484	213	487	177
511	267	514	221	517	184
541	276	544	229	547	191
571	284	574	237	577	198
601	293	604	244	607	205
631	302	634	252	637	211
661	310	664	259	667	217
691	317	694	266	697	223
721	324	724	272	727	229
751	331	754	278	757	234
781	338	784	284	787	239
811	344	814	290	817	242
841	349	844	295	847	242
871	355	874	297	877	242
901	360	904	297	907	242
931	365	934	297	937	242
961	367	964	297	967	242
991	367	994	297	997	242
1021	367	1024	297	1027	242
1051	367	1054	297	1057	242
1081	367	1084	297	1087	242
1111	367	1114	297	1117	242
1141	367	1144	297	1147	242
1171	367	1174	297	1177	242
1201	367	1204	297	1207	242
1231	367	1234	297	1237	242
1261	367	1264	297	1267	242
1291	367	1294	297	1297	242
1321	367	1324	297	1327	242
1351	367	1354	297	1357	242
1381	367	1384	297	1387	242
1411	367	1414	297	1417	242

**Table C-4. MSA BLUE MAX HazMat Model B Boot Seam vs. GB Liquid, 10 g/m<sup>2</sup>**  
**Modified Static Diffusion Test, 17 June 1998**  
**Cumulative Penetration (ng/cm<sup>2</sup>)**

Minutes	Swatch 1	Minutes	Swatch 2	Minutes	Swatch 3
10	0	13	0	16	0
40	8	43	1649	46	261
70	19	73	4931	76	865
100	27	103	8196	106	1562
130	40	133	11449	136	2263
160	54	163	14700	166	2949
190	69	193	17950	196	3607
220	83	223	21199	226	4236
250	97	253	24457	256	4842
280	109	283	27721	286	5423
310	121	313	30984	316	5978
340	131	343	34239	346	6504
370	141	373	37488	376	7001
400	151	403	40713	406	7475
430	159	433	43844	436	7931
460	167	463	46822	466	8364
490	175	493	49611	496	8775
520	182	523	52228	526	9168
550	189	553	54693	556	9541
580	196	583	57088	586	9905
610	203	613	59484	616	10269
640	210	643	61836	646	10631
670	216	673	64127	676	10992
700	223	703	66341	706	11344
730	229	733	68474	736	11684
760	234	763	70515	766	12006
790	240	793	72435	796	12311
820	245	823	74253	826	12601
850	247	853	75983	856	12870
880	247	883	77617	886	13119
910	247	913	79145	916	13352
940	247	943	80576	946	13570
970	247	973	81926	976	13776
1000	247	1003	83195	1006	13967
1030	247	1033	84410	1036	14145
1060	247	1063	85575	1066	14314
1090	247	1093	86663	1096	14473
1120	247	1123	87681	1126	14621
1150	247	1153	88617	1156	14754
1180	247	1183	89480	1186	14868
1210	247	1213	90303	1216	14965
1240	247	1243	91091	1246	15053
1270	247	1273	91858	1276	15137
1300	247	1303	92613	1306	15217
1330	247	1333	93358	1336	15293
1360	247	1363	94088	1366	15365
1390	247	1393	94803	1396	15434
1420	247	1423	95507	1426	15501

## Appendix C

**Table C-5. MSA BLUE MAX HazMat Model B Crotch Seam vs. GB Liquid, 10 g/m<sup>2</sup>**  
**Modified Static Diffusion Test, 30 June 1998**  
**Cumulative Penetration (ng/cm<sup>2</sup>)**

Minutes	Swatch 1	Minutes	Swatch 2	Minutes	Swatch 3
1	0	7	0	13	0
31	20	37	3	43	0
61	71	67	5	73	0
91	131	97	5	103	0
121	186	127	5	133	0
151	236	157	5	163	0
181	283	187	5	193	0
211	326	217	5	223	0
241	367	247	5	253	0
271	404	277	5	283	0
301	437	307	5	313	0
331	468	337	5	343	0
361	496	367	5	373	0
391	523	397	5	403	0
421	547	427	5	433	0
451	570	457	5	463	0
481	591	487	5	493	0
511	611	517	5	523	0
541	629	547	5	553	0
571	647	577	5	583	0
601	663	607	5	613	0
631	678	637	5	643	0
661	692	667	5	673	0
691	705	697	5	703	0
721	720	727	5	733	0
751	736	757	5	763	0
781	752	787	5	793	0
811	767	817	5	823	0
841	781	847	5	853	0
871	794	877	5	883	0
901	806	907	5	913	0
931	816	937	5	943	0
961	826	967	5	973	0
991	834	997	5	1003	0
1021	843	1027	5	1033	0
1051	850	1057	5	1063	0
1081	857	1087	5	1093	0
1111	863	1117	5	1123	0
1141	869	1147	5	1153	0
1171	875	1177	5	1183	0
1201	880	1207	5	1213	0
1231	886	1237	5	1243	0
1261	890	1267	5	1273	0
1291	895	1297	5	1303	0
1321	899	1327	5	1333	0
1351	904	1357	5	1363	0
1381	907	1387	5	1393	0
1411	911	1417	5	1423	0

## Appendix C